

Chapter 6

Exceptions

OCA EXAM OBJECTIVES COVERED IN THIS CHAPTER:

✓ Handling Exceptions

- Differentiate among checked exceptions, unchecked exceptions and Errors
- Create a try-catch block and determine how exceptions alter normal program flow
- Describe the advantages of Exception handling
- Create and invoke a method that throws an exception
- Recognize common exception classes (such as `NullPointerException`, `ArithmeticException`, `ArrayIndexOutOfBoundsException`, `ClassCastException`)





Many things can go wrong in a program. Java uses exceptions to deal with some of these scenarios. The OCA exam covers only the basics of working with exceptions. The rest are on the OCP exam.

Understanding Exceptions

A program can fail for just about any reason. Here are just a few possibilities:

- The code tries to connect to a website, but the Internet connection is down.
- You made a coding mistake and tried to access an invalid index in an array.
- One method calls another with a value that the method doesn't support.

As you can see, some of these are coding mistakes. Others are completely beyond your control. Your program can't help it if the Internet connection goes down. What it *can* do is deal with the situation.

First, we'll look at the role of exceptions. Then we'll cover the various types of exceptions, followed by an explanation of how to throw an exception in Java.

The Role of Exceptions

An *exception* is Java's way of saying, "I give up. I don't know what to do right now. You deal with it." When you write a method, you can either deal with the exception or make it the calling code's problem.

As an example, think of Java as a child who visits the zoo. The *happy path* is when nothing goes wrong. The child continues to look at the animals until the program nicely ends. Nothing went wrong and there were no exceptions to deal with.

This child's younger sister doesn't experience the happy path. In all the excitement she trips and falls. Luckily, it isn't a bad fall. The little girl gets up and proceeds to look at more animals. She has handled the issue all by herself. Unfortunately, she falls again later in the day and starts crying. This time, she has declared she needs help by crying. The story ends well. Her daddy rubs her knee and gives her a hug. Then they go back to seeing more animals and enjoy the rest of the day.

These are the two approaches Java uses when dealing with exceptions. A method can handle the exception case itself or make it the caller's responsibility. You saw both in the trip to the zoo.

You saw an exception in Chapter 1, “Java Building Blocks,” with a very simple Zoo example. You wrote a class that printed out the name of the zoo:

```
1: public class Zoo {  
2:   public static void main(String[] args) {  
3:     System.out.println(args[0]);  
4:     System.out.println(args[1]);  
5:   } }
```

Then you tried to call it without enough arguments:

```
$ javac Zoo.java  
$ java Zoo Zoo
```

On line 4, Java realized there’s only one **element** in the array and index 1 is not allowed. Java threw up its hands in defeat and **threw an exception**. It didn’t try to handle the exception. It just said, **“I can’t deal with it”** and the exception was displayed:

```
ZooException in thread "main"  
java.lang.ArrayIndexOutOfBoundsException: 1  
at mainmethod.Zoo.main(Zoo.java:7)
```

Exceptions can and do occur all the time, even in solid program code. In our example, toddlers falling is a **fact of life**. When you write more advanced programs, you’ll need to **deal with failures** in accessing files, networks, and outside services. On the OCA exam, exceptions deal largely with **mistakes in programs**. For example, a program might try to access an invalid position in an array. The key point to remember is that exceptions alter the program flow.



Real World Scenario

Return Codes vs. Exceptions

Exceptions are used when “something goes wrong.” However, the word **“wrong”** is subjective. The following code returns **-1** instead of throwing an exception if no match is found:

```
public int indexOf(String[] names, String name) {  
    for (int i = 0; i < names.length; i++) {  
        if (names[i].equals(name)) { return i; }  
    }  
    return -1;  
}
```

continues

continued

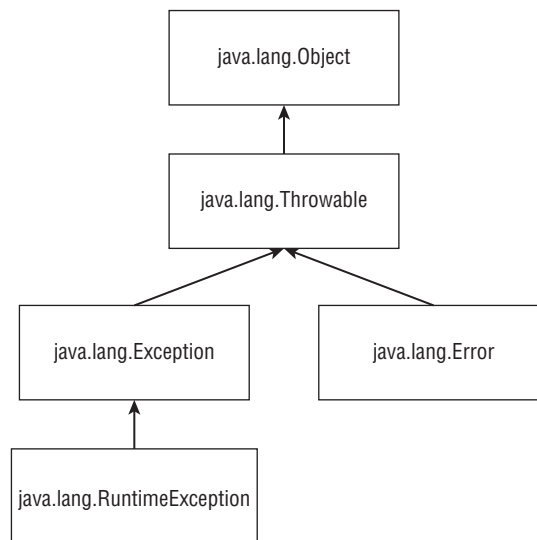
This approach is common when writing a method that does a search. For example, imagine being asked to find the name Joe in the array. It is perfectly reasonable that Joe might not appear in the array. When this happens, a special value is returned. An exception should be reserved for exceptional conditions like *names* being null.

In general, try to avoid return codes. Return codes are commonly used in searches, so programmers are expecting them. In other methods, you will take your callers by surprise by returning a special value. An exception forces the program to deal with them or end with the exception if left unhandled, whereas a return code could be accidentally ignored and cause problems later in the program. An exception is like shouting, “Deal with me!”

Understanding Exception Types

As we’ve explained, an exception is an **event** that **alters program flow**. Java has a **Throwable superclass** for all objects that represent these events. Not all of them have the word exception in their classname, **which can be confusing**. Figure 6.1 shows the key subclasses of Throwable.

FIGURE 6.1 Categories of exception



Error means something went so horribly wrong that your program **should not attempt** to recover from it. For example, the disk drive **“disappeared.”** These are abnormal conditions that you aren’t likely to encounter.

A *runtime exception* is defined as the RuntimeException class and its subclasses. Runtime exceptions tend to be **unexpected** but **not necessarily fatal**. For example, accessing an invalid array index is **unexpected**. Runtime exceptions are also known as **unchecked exceptions**.

Runtime vs. at the Time the Program is Run

A runtime (unchecked) exception is a specific type of exception. All exceptions occur at the time that the program is run. (The alternative is compile time, which would be a compiler error.) People don't refer to them as run time exceptions because that would be too easy to confuse with runtime! When you see runtime, it means unchecked.

A *checked exception* includes `Exception` and all subclasses that do not extend `RuntimeException`. Checked exceptions tend to be more anticipated—for example, trying to read a file that doesn't exist.

Checked exceptions? What are we checking? Java has a rule called the *handle or declare rule*. For checked exceptions, Java requires the code to either *handle* them or *declare* them in the method signature.

For example, this method declares that it might throw an exception:

```
void fall() throws Exception {  
    throw new Exception();  
}
```

Notice that you're using two different keywords here. `throw` tells Java that you want to *throw an Exception*. `throws` simply *declares* that the method *might* throw an `Exception`. It *also might not*. You will see the `throws` keyword more later in the chapter.

Because checked exceptions tend to be *anticipated*, Java enforces that the programmer do something to show the *exception was thought about*. Maybe it was handled in the method. Or maybe the method declares that it can't handle the exception and someone else should.

An example of a runtime exception is a `NullPointerException`, which happens when you try to call a member on a null reference. This can occur in any method. If you had to declare runtime exceptions everywhere, every single method would have that clutter!

Checked vs. Unchecked (Runtime) Exceptions

In the past, developers used checked exceptions more often than they do now. According to Oracle, they are intended for issues a programmer "might reasonably be expected to recover from." Then developers started writing code where a chain of methods kept declaring the same exception and nobody actually handled it. Some libraries started using runtime exceptions for issues a programmer might reasonably be expected to recover from. Many programmers can hold a debate with you on which approach is better. For the OCA exam, you need to know the rules for how checked versus unchecked exceptions function. You don't have to decide philosophically whether an exception should be checked or unchecked.

Throwing an Exception

Any Java code can throw an exception; this includes code you write. For the OCP exam, you'll learn how to create your own exception classes. The OCA exam is limited to exceptions that someone else has created. Most likely, they will be exceptions that are provided with Java. You might encounter an exception that was made up for the exam. This is fine. The question will make it obvious that these are exceptions by having the classname end with exception. For example, "MyMadeUpException" is clearly an exception.

On the exam, you will see two types of code that result in an exception. The first is code that's wrong. For example:

```
String[] animals = new String[0];  
System.out.println(animals[0]);
```

This code throws an `ArrayIndexOutOfBoundsException`. That means questions about exceptions can be hidden in questions that appear to be about something else.



On the OCA exam, the vast majority of questions have a choice about not compiling and about throwing an exception. Pay special attention to code that calls a method on a null or that references an invalid array or ArrayList index. If you spot this, you know the correct answer is that the code throws an exception.

The second way for code to result in an exception is to explicitly request Java to throw one. Java lets you write statements like these:

```
throw new Exception();  
throw new Exception("Ow! I fell.");  
throw new RuntimeException();  
throw new RuntimeException("Ow! I fell.");
```

The throw keyword tells Java you want some other part of the code to deal with the exception. This is the same as the young girl crying for her daddy. Someone else needs to figure out what to do about the exception.

When creating an exception, you can usually pass a String parameter with a message or you can pass no parameters and use the defaults. We say *usually* because this is a convention. Someone could create an exception class that does not have a constructor that takes a message. The first two examples create a new object of type Exception and throw it. The last two show that the code looks the same regardless of which type of exception you throw.

These rules are very important. Be sure to closely study everything in Table 6.1.

TABLE 6.1 Types of exceptions

Type	How to recognize	Okay for program to catch?	Is program required to handle or declare?
Runtime exception	Subclass of <code>RuntimeException</code>	Yes	No
Checked exception	Subclass of <code>Exception</code> but not subclass of <code>RuntimeException</code>	Yes	Yes
Error	Subclass of <code>Error</code>	No	No

Using a *try* Statement

Now that you know what exceptions are, let's explore how to handle them. Java uses a *try statement* to separate the logic that might throw an exception from the logic to handle that exception. Figure 6.2 shows the syntax of a try statement.

FIGURE 6.2 The syntax of a *try* statement



The code in the `try` block is run normally. If any of the statements throw an exception that can be caught by the exception type listed in the `catch` block, the `try` block stops running and execution goes to the `catch` statement. If none of the statements in the `try` block throw an exception that can be caught, the *catch clause* is not run.

You probably noticed the words “block” and “clause” used interchangeably. The exam does this as well, so we are getting you used to it. Both are correct. “Block” is correct because there are braces present. “Clause” is correct because they are part of a `try` statement.

There aren’t a ton of syntax rules here. The curly braces are required for the `try` and `catch` blocks.

In our example, the little girl gets up by herself the first time she falls. Here’s what this looks like:

```
3: void explore() {
4:   try {
5:     fall();
6:     System.out.println("never get here");
7:   } catch (RuntimeException e) {
8:     getUp();
9:   }
10:  seeAnimals();
11: }
12: void fall() { throw new RuntimeException(); }
```

First, line 5 calls the `fall()` method. Line 12 throws an exception. This means Java jumps straight to the `catch` block, skipping line 6. The girl gets up on line 8. Now the `try` statement is over and execution proceeds normally with line 10.

Now let’s look at some invalid `try` statements that the exam might try to trick you with. Do you see what’s wrong with this one?

```
try // DOES NOT COMPILE
    fall();
catch (Exception e)
    System.out.println("get up");
```

The problem is that the braces are missing. It needs to look like this:

```
try {
    fall();
} catch (Exception e) {
    System.out.println("get up");
}
```


try statements are like methods in that the curly braces are required even if there is only one statement inside the code blocks. *if* statements and loops are special in this respect as they allow you to omit the curly braces.

What about this one?

```
try { // DOES NOT COMPILE
    fall();
}
```

This code doesn't compile because the *try* block doesn't have anything after it. Remember, the point of a *try* statement is for something to happen if an exception is thrown. Without another clause, the *try* statement is lonely.

Now that you know the basics, let's start adding more features to exceptions. The following sections show you how to add a *finally* clause to a *try* statement and catch different types of exceptions and describe what happens if an exception is thrown in *catch* or *finally*.

Adding a *finally* Block

The *try* statement also lets you run code at the end with a *finally clause* regardless of whether an exception is thrown. Figure 6.3 shows the syntax of a *try* statement with this extra functionality.

FIGURE 6.3 The syntax of a *try* statement with *finally*



There are two paths through code with both a *catch* and a *finally*. If an exception is thrown, the *finally* block is run after the *catch* block. If no exception is thrown, the *finally* block is run after the *try* block completes.

Let's go back to our young girl example, this time with `finally`:

```
12: void explore() {
13:   try {
14:     seeAnimals();
15:     fall();
16:   } catch (Exception e) {
17:     getHugFromDaddy();
18:   } finally {
19:     seeMoreAnimals();
20:   }
21:   goHome();
22: }
```

The girl falls on line 15. If she gets up by herself, the code goes on to the `finally` block and runs line 19. Then the `try` statement is over and the code proceeds on line 21. If the girl doesn't get up by herself, she throws an exception. The `catch` block runs and she gets a hug on line 17. Then the `try` statement is over and the code proceeds on line 21. Either way, the ending is the same. The `finally` block is executed and the `try` statement ends.



On the OCA exam, a `try` statement must have `catch` and/or `finally`. Having both is fine. Having neither is a problem. On the OCP exam, you'll learn about a special syntax for a `try` statement called `try-with-resources` that allows neither a `catch` nor a `finally` block. On the OCA exam, you get to assume a `try` statement is just a regular `try` statement and not a `try-with-resources` statement.

The exam will try to trick you with missing clauses or clauses in the wrong order. Do you see why the following do or do not compile?

```
25: try { // DOES NOT COMPILE
26:   fall();
27: } finally {
28:   System.out.println("all better");
29: } catch (Exception e) {
30:   System.out.println("get up");
31: }
32:
33: try { // DOES NOT COMPILE
34:   fall();
35: }
36:
37: try {
```

```
38:  fall();
39: } finally {
40:  System.out.println("all better");
41: }
```

The first example (lines 25–31) does not compile because the `catch` and `finally` blocks are in the wrong order. The second example (lines 33–35) does not compile because there must be a `catch` or `finally` block. The third example (lines 37–41) is just fine. `catch` is not required if `finally` is present.

One problem with `finally` is that any realistic uses for it are out of the scope of the OCA exam. `finally` is typically used to close resources such as files or databases—both of which are topics on the OCP exam. This means most of the examples you encounter on the OCA exam with `finally` are going to look contrived. For example, you'll get asked questions such as what this code outputs:

```
String s = "";
try {
    s += "t";
} catch(Exception e) {
    s += "c";
} finally {
    s += "f";
}
s += "a";
System.out.print(s);
```

The answer is `tfa`. The `try` block is executed. Since no exception is thrown, Java goes straight to the `finally` block. Then the code after the `try` statement is run. We know; this is a silly example. Expect to see examples like this on the OCA exam.

System.exit

There is one exception to “the `finally` block always runs after the `catch` block” rule: Java defines a method that you call as `System.exit(0)`; . The integer parameter is the error code that gets returned. `System.exit` tells Java, “Stop. End the program right now. Do not pass go. Do not collect \$200.” When `System.exit` is called in the `try` or `catch` block, `finally` does not run.

Catching Various Types of Exceptions

So far, you have been catching only one type of exception. Now let's see what happens when different types of exceptions can be thrown from the same method.

Creating your own exceptions is not on the OCA exam, but it is on the OCP exam. However, the OCA exam can define basic exceptions to show you the hierarchy. You only need to do two things with this information. First, you must be able to recognize if the exception is a checked or an unchecked exception. Second, you need to determine if any of the exceptions are subclasses of the others.

```
class AnimalsOutForAWalk extends RuntimeException { }  
class ExhibitClosed extends RuntimeException { }  
class ExhibitClosedForLunch extends ExhibitClosed { }
```

In this example, there are three custom exceptions. All are unchecked exceptions because they directly or indirectly extend `RuntimeException`. Now we catch both types of exceptions and handle them by printing out the appropriate message:

```
public void visitPorcupine() {  
    try {  
        seeAnimal();  
    } catch (AnimalsOutForAWalk e) { // first catch block  
        System.out.print("try back later");  
    } catch (ExhibitClosed e) { // second catch block  
        System.out.print("not today");  
    }  
}
```

There are three possibilities for when this code is run. If `seeAnimal()` doesn't throw an exception, nothing is printed out. If the animal is out for a walk, only the first catch block runs. If the exhibit is closed, only the second catch block runs.

A rule exists for the order of the catch blocks. Java looks at them in the order they appear. If it is impossible for one of the catch blocks to be executed, a compiler error about unreachable code occurs. This happens when a superclass is caught before a subclass. Remember, we warned you to pay attention to any subclass exceptions.

In the porcupine example, the order of the catch blocks could be reversed because the exceptions don't inherit from each other. And yes, we have seen a porcupine be taken for a walk on a leash.

The following example shows exception types that do inherit from each other:

```
public void visitMonkeys() {  
    try {  
        seeAnimal();  
    } catch (ExhibitClosedForLunch e) { // subclass exception  
        System.out.print("try back later");  
    } catch (ExhibitClosed e) { // superclass exception  
        System.out.print("not today");  
    }  
}
```

If the more specific `ExhibitClosedForLunch` exception is thrown, the first catch block runs. If not, Java checks if the superclass `ExhibitClosed` exception is thrown and catches it. This time, the order of the catch blocks does matter. The reverse does not work.

```
public void visitMonkeys() {
    try {
        seeAnimal();
    } catch (ExhibitClosed e) {
        System.out.print("not today");
    } catch (ExhibitClosedForLunch e) { // DOES NOT COMPILE
        System.out.print("try back later");
    }
}
```

This time, if the more specific `ExhibitClosedForLunch` exception is thrown, the catch block for `ExhibitClosed` runs—which means there is no way for the second catch block to ever run. Java correctly tells us there is an unreachable catch block.

Let's try this one more time. Do you see why this code doesn't compile?

```
public void visitSnakes() {
    try {
        seeAnimal();
    } catch (RuntimeException e) {
        System.out.print("runtime exception");
    } catch (ExhibitClosed e) { // DOES NOT COMPILE
        System.out.print("not today");
    } catch (Exception e) {
        System.out.print("exception");
    }
}
```

It's the same problem. `ExhibitClosed` is a `RuntimeException`. If it is thrown, the first catch block takes care of it, making sure there no way to get to the second catch block.

To review catching multiple exceptions, remember that at most one catch block will run and it will be the first catch block that can handle it.

Throwing a Second Exception

So far, we've limited ourselves to one try statement in each example. However, a catch or finally block can have any valid Java code in it—including another try statement.



Even though the topic of reading files is on the OCP exam, the OCA exam may ask you about exception handling with those classes. This is actually a gift. When you see such a question, you know the problem has to be about basic Java syntax or exception handling!

The following code tries to read a file:

```
16: public static void main(String[] args) {
17:     FileReader reader = null;
18:     try {
19:         reader = read();
20:     } catch (IOException e) {
21:         try {
22:             if (reader != null) reader.close();
23:         } catch (IOException inner) {
24:             }
25:     }
26: }
27: private static FileReader read() throws IOException {
28:     // CODE GOES HERE
29: }
```

The easiest case is if line 28 doesn't throw an exception. Then the entire catch block on lines 20–25 is skipped. Next, consider if line 28 throws a `NullPointerException`. That isn't an `IOException`, so the catch block on lines 20–25 will still be skipped.

If line 28 does throw an `IOException`, the catch block on lines 20–25 does get run. Line 22 tries to close the reader. If that goes well, the code completes and the `main()` method ends normally. If the `close()` method does throw an exception, Java looks for more catch blocks. There aren't any, so the `main` method throws that new exception. Regardless, the exception on line 28 is handled. A different exception might be thrown, but the one from line 28 is done.

Most of the examples you see with exception handling on the exam are abstract. They use letters or numbers to make sure you understand the flow. This one shows that only the last exception to be thrown matters. (This is true for the OCA exam. It will change a bit on the OCP exam.)

```
26: try {
27:     throw new RuntimeException();
28: } catch (RuntimeException e) {
29:     throw new RuntimeException();
30: } finally {
31:     throw new Exception();
32: }
```

Line 27 throws an exception, which is caught on line 28. The catch block then throws an exception on line 29. If there were no `finally` block, the exception from line 29 would

be thrown. However, the `finally` block runs after the `try` block. Since the `finally` block throws an exception of its own on line 31, this one gets thrown. The exception from the `catch` block gets forgotten about. This is why you often see another `try/catch` inside a `finally` block—to make sure it doesn't mask the exception from the `catch` block.

Next we are going to show you the hardest example you can be asked related to exceptions. What do you think this method returns? Go slowly. It's tricky.

```
30: public String exceptions() {
31:     String result = "";
32:     String v = null;
33:     try {
34:         try {
35:             result += "before";
36:             v.length();
37:             result += "after";
38:         } catch (NullPointerException e) {
39:             result += "catch";
40:             throw new RuntimeException();
41:         } finally {
42:             result += "finally";
43:             throw new Exception();
44:         }
45:     } catch (Exception e) {
46:         result += "done";
47:     }
48:     return result;
49: }
```

The correct answer is `before catch finally done`. Everything is normal up until line 35, when "before" is added. Line 36 throws a `NullPointerException`. Line 37 is skipped as Java goes straight to the `catch` block. Line 38 does catch the exception, and "catch" is added on line 39. Then line 40 throws a `RuntimeException`. The `finally` block runs after the `catch` regardless of whether an exception is thrown; it adds "finally" to result. At this point, we have completed the inner `try` statement that ran on lines 34–44. The outer `catch` block then sees an exception was thrown and catches it on line 45; it adds "done" to result.

Recognizing Common Exception Types

You need to recognize three types of exceptions for the OCA exam: runtime exceptions, checked exceptions, and errors. We'll look at common examples of each type. For the exam, you'll need to recognize which type of an exception it is and whether it's thrown by the JVM or a programmer. So you can recognize them, we'll show you some code examples for those exceptions.

Runtime Exceptions

Runtime exceptions extend `RuntimeException`. They don't have to be handled or declared. They can be thrown by the programmer or by the JVM. Common runtime exceptions include the following:

ArithmeticException Thrown by the JVM when code attempts to divide by zero

ArrayIndexOutOfBoundsException Thrown by the JVM when code uses an illegal index to access an array

ClassCastException Thrown by the JVM when an attempt is made to cast an exception to a subclass of which it is not an instance

IllegalArgumentException Thrown by the programmer to indicate that a method has been passed an illegal or inappropriate argument

NullPointerException Thrown by the JVM when there is a null reference where an object is required

NumberFormatException Thrown by the programmer when an attempt is made to convert a string to a numeric type but the string doesn't have an appropriate format

ArithmeticException

Trying to divide an `int` by zero gives an undefined result. When this occurs, the JVM will throw an `ArithmeticException`:

```
int answer = 11 / 0;
```

Running this code results in the following output:

```
Exception in thread "main" java.lang.ArithmeticException: / by zero
```

Java doesn't spell out the word "divide." That's okay, though, because we know that `/` is the division operator and that Java is trying to tell us division by zero occurred.

The thread "main" is telling us the code was called directly or indirectly from a program with a `main` method. On the OCA exam, this is all the output we will see. Next comes the name of the exception, followed by extra information (if any) that goes with the exception.

ArrayIndexOutOfBoundsException

You know by now that array indexes start with 0 and go up to 1 less than the length of the array—which means this code will throw an `ArrayIndexOutOfBoundsException`:

```
int[] countsOfMoose = new int[3];  
System.out.println(countsOfMoose[-1]);
```

This is a problem because there's no such thing as a negative array index. Running this code yields the following output:

```
Exception in thread "main" java.lang.ArrayIndexOutOfBoundsException: -1
```

At least Java tells us what index was invalid. Can you see what's wrong with this one?


```
int total = 0;
int[] countsOfMoose = new int[3];
for (int i = 0; i <= countsOfMoose.length; i++)
    total += countsOfMoose[i];
```

The problem is that the for loop should have `<` instead of `<=`. On the final iteration of the loop, Java tries to call `countsOfMoose[3]`, which is invalid. The array includes only three elements, making 2 the largest possible index. The output looks like this:

```
Exception in thread "main" java.lang.ArrayIndexOutOfBoundsException: 3
```

ClassCastException

Java tries to protect you from impossible casts. This code doesn't compile because `Integer` is not a subclass of `String`:

```
String type = "moose";
Integer number = (Integer) type; // DOES NOT COMPILE
```

More complicated code thwarts Java's attempts to protect you. When the cast fails at runtime, Java will throw a `ClassCastException`:

```
String type = "moose";
Object obj = type;
Integer number = (Integer) obj;
```

The compiler sees a cast from `Object` to `Integer`. This could be okay. The compiler doesn't realize there's a `String` in that `Object`. When the code runs, it yields the following output:

```
Exception in thread "main" java.lang.ClassCastException: java.lang.String
cannot be cast to java.lang.Integer
```

Java tells us both types that were involved in the problem, making it apparent what's wrong.

IllegalArgumentException

`IllegalArgumentException` is a way for your program to protect itself. We first saw the following setter method in the `Swan` class in Chapter 4, "Methods and Encapsulation."

```
6: public void setNumberEggs(int numberEggs) { // setter
7:     if (numberEggs >= 0) // guard condition
8:         this.numberEggs = numberEggs;
9: }
```

This code works, but we don't really want to ignore the caller's request when they tell us a `Swan` has `-2` eggs. We want to tell the caller that something is wrong—preferably in a very obvious way that the caller can't ignore so that the programmer will fix the problem. Exceptions are an efficient way to do this. Seeing the code end with an exception is a great reminder that something is wrong:

```
public static void setNumberEggs(int numberEggs) {  
    if (numberEggs < 0)  
        throw new IllegalArgumentException(  
            "# eggs must not be negative");  
    this.numberEggs = numberEggs;  
}
```

The program throws an exception when it's not happy with the parameter values. The output looks like this:

```
Exception in thread "main" java.lang.IllegalArgumentException: # eggs must not  
be negative
```

Clearly this is a problem that must be fixed if the programmer wants the program to do anything useful.

NullPointerException

Instance variables and methods must be called on a non-null reference. If the reference is null, the JVM will throw a `NullPointerException`. It's usually subtle, such as this example, which checks whether you remember instance variable references default to null.

```
String name;
```

```
public void printLength() throws NullPointerException {  
    System.out.println(name.length());  
}
```

Running this code results in this output:

```
Exception in thread "main" java.lang.NullPointerException
```

NumberFormatException

Java provides methods to convert strings to numbers. When these are passed an invalid value, they throw a `NumberFormatException`. The idea is similar to `IllegalArgumentException`. Since this is a common problem, Java gives it a separate class. In fact, `NumberFormatException` is a subclass of `IllegalArgumentException`. Here's an example of trying to convert something non-numeric into an `int`:

```
Integer.parseInt("abc");
```

The output looks like this:

```
Exception in thread "main" java.lang.NumberFormatException: For input string:  
"abc"
```

Checked Exceptions

Checked exceptions have `Exception` in their hierarchy but not `RuntimeException`. They must be handled or declared. They can be thrown by the programmer or by the JVM. Common runtime exceptions include the following:

`FileNotFoundException` Thrown programmatically when code tries to reference a file that does not exist

`IOException` Thrown programmatically when there's a problem reading or writing a file

For the OCA exam, you only need to know that these are checked exceptions. Also keep in mind that `FileNotFoundException` is a subclass of `IOException`, although the exam will remind you of that fact if it comes up. You'll see these two exceptions in more detail on the OCP exam.

Errors

Errors extend the `Error` class. They are thrown by the JVM and should not be handled or declared. Errors are rare, but you might see these:

`ExceptionInInitializerError` Thrown by the JVM when a static initializer throws an exception and doesn't handle it

`StackOverflowError` Thrown by the JVM when a method calls itself too many times (this is called *infinite recursion* because the method typically calls itself without end)

`NoClassDefFoundError` Thrown by the JVM when a class that the code uses is available at compile time but not runtime

ExceptionInInitializerError

Java runs static initializers the first time a class is used. If one of the static initializers throws an exception, Java can't start using the class. It declares defeat by throwing an `ExceptionInInitializerError`. This code shows an `ArrayIndexOutOfBoundsException` in a static initializer:

```
static {
    int[] countsOfMoose = new int[3];
    int num = countsOfMoose[-1];
}
public static void main(String[] args) { }
```

This code yields information about two exceptions:

```
Exception in thread "main" java.lang.ExceptionInInitializerError
Caused by: java.lang.ArrayIndexOutOfBoundsException: -1
```

We get the `ExceptionInInitializerError` because the error happened in a static initializer. That information alone wouldn't be particularly useful in fixing the problem. Therefore, Java also tells us the original cause of the problem: the `ArrayIndexOutOfBoundsException` that we need to fix.

The `ExceptionInInitializerError` is an error because Java failed to load the whole class. This failure prevents Java from continuing.

StackOverflowError

When Java calls methods, it puts parameters and local variables on the stack. After doing this a very large number of times, the stack runs out of room and overflows. This is called a `StackOverflowError`. Most of the time, this error occurs when a method calls itself.

```
public static void doNotCodeThis(int num) {
    doNotCodeThis(1);
}
```

The output contains this line:

```
Exception in thread "main" java.lang.StackOverflowError
```

Since the method calls itself, it will never end. Eventually, Java runs out of room on the stack and throws the error. This is called infinite recursion. It is better than an infinite loop because at least Java will catch it and throw the error. With an infinite loop, Java just uses all your CPU until you can kill it.

NoClassDefFoundError

This error won't show up in code on the exam—you just need to know that it is an error. `NoClassDefFoundError` occurs when Java can't find the class at runtime.

Calling Methods That Throw Exceptions

When you're calling a method that throws an exception, the rules are the same as within a method. Do you see why the following doesn't compile?

```
class NoMoreCarrotsException extends Exception {}
public class Bunny {
    public static void main(String[] args) {
        eatCarrot();// DOES NOT COMPILE
    }
    private static void eatCarrot() throws NoMoreCarrotsException {
    }
}
```

The problem is that `NoMoreCarrotsException` is a checked exception. Checked exceptions must be handled or declared. The code would compile if we changed the `main()` method to either of these:

```
public static void main(String[] args)
    throws NoMoreCarrotsException { // declare exception
    eatCarrot();
}
public static void main(String[] args) {
    try {
        eatCarrot();
    } catch (NoMoreCarrotsException e ) { // handle exception
        System.out.print("sad rabbit");
    }
}
```

You might have noticed that `eatCarrot()` didn't actually throw an exception; it just declared that it could. This is enough for the compiler to require the caller to handle or declare the exception.

The compiler is still on the lookout for unreachable code. Declaring an unused exception isn't considered unreachable code. It gives the method the option to change the implementation to throw that exception in the future. Do you see the issue here?

```
public void bad() {
    try {
        eatCarrot();
    } catch (NoMoreCarrotsException e ) { // DOES NOT COMPILE
        System.out.print("sad rabbit");
    }
}
public void good() throws NoMoreCarrotsException {
    eatCarrot();
}
private static void eatCarrot() { }
```

Java knows that `eatCarrot()` can't throw a checked exception—which means there's no way for the catch block in `bad()` to be reached. In comparison, `good()` is free to declare other exceptions.

Subclasses

Now that you have a deeper understanding of exceptions, let's look at overriding methods with exceptions in the method declaration. When a class overrides a method from a

superclass or implements a method from an interface, it's not allowed to add new checked exceptions to the method signature. For example, this code isn't allowed:

```
class CanNotHopException extends Exception { }
class Hopper {
    public void hop() { }
}
class Bunny extends Hopper {
    public void hop() throws CanNotHopException { } // DOES NOT COMPILE
}
```

Java knows `hop()` isn't allowed to throw any checked exceptions because the superclass `Hopper` doesn't declare any. Imagine what would happen if subclasses could add checked exceptions—you could write code that calls `Hopper`'s `hop()` method and not handle any exceptions. Then if `Bunny` was used in its place, the code wouldn't know to handle or declare `CanNotHopException`.

A subclass is allowed to declare fewer exceptions than the superclass or interface. This is legal because callers are already handling them.

```
class Hopper {
    public void hop() throws CanNotHopException { }
}
class Bunny extends Hopper {
    public void hop() { }
}
```

A subclass not declaring an exception is similar to a method declaring it throws an exception that it never actually throws. This is perfectly legal.

Similarly, a class is allowed to declare a subclass of an exception type. The idea is the same. The superclass or interface has already taken care of a broader type. Here's an example:

```
class Hopper {
    public void hop() throws Exception { }
}
class Bunny extends Hopper {
    public void hop() throws CanNotHopException { }
}
```

`Bunny` could declare that it throws `Exception` directly, or it could declare that it throws a more specific type of `Exception`. It could even declare that it throws nothing at all.

This rule applies only to checked exceptions. The following code is legal because it has a runtime exception in the subclass's version:

```
class Hopper {
    public void hop() { }
}
```

```
class Bunny extends Hopper {  
    public void hop() throws IllegalStateException { }  
}
```

The reason that it's okay to declare new runtime exceptions in a subclass method is that the declaration is redundant. Methods are free to throw any runtime exceptions they want without mentioning them in the method declaration.

Printing an Exception

There are three ways to print an exception. You can let Java print it out, print just the message, or print where the stack trace comes from. This example shows all three approaches:

```
5: public static void main(String[] args) {  
6:     try {  
7:         hop();  
8:     } catch (Exception e) {  
9:         System.out.println(e);  
10:        System.out.println(e.getMessage());  
11:        e.printStackTrace();  
12:    }  
13: }  
14: private static void hop() {  
15:     throw new RuntimeException("cannot hop");  
16: }
```

This code results in the following output:

```
java.lang.RuntimeException: cannot hop  
cannot hop  
java.lang.RuntimeException: cannot hop  
at trycatch.Handling.hop(Handling.java:15)  
at trycatch.Handling.main(Handling.java:7)
```

The first line shows what Java prints out by default: the exception type and message. The second line shows just the message. The rest shows a stack trace.

The stack trace is usually the most helpful one because it shows where the exception occurred in each method that it passed through. On the OCA exam, you will mostly see the first approach. This is because the exam often shows code snippets.

The stack trace shows all the methods on the stack. Figure 6.4 shows what the stack looks like for this code. Every time you call a method, Java adds it to the stack until it completes. When an exception is thrown, it goes through the stack until it finds a method that can handle it or it runs out of stack.

FIGURE 6.4 A method stack

Real World Scenario

Why Swallowing Exception Is Bad

Because checked exceptions require you to handle or declare them, there is a temptation to catch them so they “go away.” But doing so can cause problems. In the following code, there’s a problem reading in the file:

```
public static void main(String[] args) {
    String textInFile = null;
    try {
        readInFile();
    } catch (IOException e) {
        // ignore exception
    }
    // imagine many lines of code here
    System.out.println(textInFile.replace(" ", ""));
}

private static void readInFile() throws IOException {
    throw new IOException();
}
```

The code results in a `NullPointerException`. Java doesn’t tell you anything about the original `IOException` because it was handled. Granted, it was handled poorly, but it *was* handled.

When writing your own code, print out a stack trace or at least a message when catching an exception. Also, consider whether continuing is the best course of action. In our example, the program can’t do anything after it fails to read in the file. It might as well have just thrown the `IOException`.

Summary

An exception indicates something unexpected happened. A method can handle an exception by catching it or declaring it for the caller to deal with. Many exceptions are thrown by Java libraries. You can throw your own exception with code such as `throw new Exception()`.

Subclasses of `java.lang.Error` are exceptions that a programmer should not attempt to handle. Subclasses of `java.lang.RuntimeException` are runtime (unchecked) exceptions. Subclasses of `java.lang.Exception`, but not `java.lang.RuntimeException` are checked exceptions. Java requires checked exceptions to be handled or declared.

If a `try` statement has multiple catch blocks, at most one catch block can run. Java looks for an exception that can be caught by each catch block in the order they appear, and the first match is run. Then execution continues after the `try` statement. If both `catch` and `finally` throw an exception, the one from `finally` gets thrown.

Common runtime exceptions include:

- `ArithmeticException`
- `ArrayIndexOutOfBoundsException`
- `ClassCastException`
- `IllegalArgumentException`
- `NullPointerException`
- `NumberFormatException`

`IllegalArgumentException` and `NumberFormatException` are typically thrown by the programmer, whereas the others are typically thrown by the JVM.

Common checked exceptions include:

- `IOException`
- `FileNotFoundException`

Common errors include:

- `ExceptionInInitializerError`
- `StackOverflowError`
- `NoClassDefFoundError`

When a method overrides a method in a superclass or interface, it is not allowed to add checked exceptions. It is allowed to declare fewer exceptions or declare a subclass of a declared exception. Methods declare exceptions with the keyword `throws`.

Exam Essentials

Differentiate between checked and unchecked exceptions. Unchecked exceptions are also known as runtime exceptions and are subclasses of `java.lang.RuntimeException`. All other subclasses of `java.lang.Exception` are checked exceptions.

Understand the flow of a try statement. A try statement must have a catch or a finally block. Multiple catch blocks are also allowed, provided no superclass exception type appears in an earlier catch block than its subclass. The finally block runs last regardless of whether an exception is thrown.

Identify whether an exception is thrown by the programmer or the JVM. `IllegalArgumentException` and `NumberFormatException` are commonly thrown by the programmer. Most of the other runtime exceptions are typically thrown by the JVM.

Declare methods that declare exceptions. The `throws` keyword is used in a method declaration to indicate an exception might be thrown. When overriding a method, the method is allowed to throw fewer exceptions than the original version.

Recognize when to use `throw` versus `throws`. The `throw` keyword is used when you actually want to throw an exception—for example, `throw new RuntimeException()`. The `throws` keyword is used in a method declaration.

Review Questions

1. Which of the following statements are true? (Choose all that apply)
 - A. Runtime exceptions are the same thing as checked exceptions.
 - B. Runtime exceptions are the same thing as unchecked exceptions.
 - C. You can declare only checked exceptions.
 - D. You can declare only unchecked exceptions.
 - E. You can handle only `Exception` subclasses.
2. Which of the following pairs fill in the blanks to make this code compile? (Choose all that apply)

```
7: public void ohNo() _____ Exception {  
8:     _____ Exception();  
9: }
```

 - A. On line 7, fill in `throw`
 - B. On line 7, fill in `throws`
 - C. On line 8, fill in `throw`
 - D. On line 8, fill in `throw new`
 - E. On line 8, fill in `throws`
 - F. On line 8, fill in `throws new`
3. When are you required to use a `finally` block in a regular `try` statement (not a `try-with-resources`)?
 - A. Never.
 - B. When the program code doesn't terminate on its own.
 - C. When there are no `catch` blocks in a `try` statement.
 - D. When there is exactly one `catch` block in a `try` statement.
 - E. When there are two or more `catch` blocks in a `try` statement.
4. Which exception will the following throw?

```
Object obj = new Integer(3);  
String str = (String) obj;  
System.out.println(str);
```

 - A. `ArrayIndexOutOfBoundsException`
 - B. `ClassCastException`
 - C. `IllegalArgumentException`
 - D. `NumberFormatException`
 - E. None of the above.

5. Which of the following exceptions are thrown by the JVM? (Choose all that apply)
- A. `ArrayIndexOutOfBoundsException`
 - B. `ExceptionInInitializerError`
 - C. `java.io.IOException`
 - D. `NullPointerException`
 - E. `NumberFormatException`
6. What will happen if you add the statement `System.out.println(5 / 0);` to a working `main()` method?
- A. It will not compile.
 - B. It will not run.
 - C. It will run and throw an `ArithmeticException`.
 - D. It will run and throw an `IllegalArgumentException`.
 - E. None of the above.
7. What is printed besides the stack trace caused by the `NullPointerException` from line 16?

```
1: public class DoSomething {  
2:     public void go() {  
3:         System.out.print("A");  
4:         try {  
5:             stop();  
6:         } catch (ArithmeticException e) {  
7:             System.out.print("B");  
8:         } finally {  
9:             System.out.print("C");  
10:        }  
11:        System.out.print("D");  
12:    }  
13:    public void stop() {  
14:        System.out.print("E");  
15:        Object x = null;  
16:        x.toString();  
17:        System.out.print("F");  
18:    }  
19:    public static void main(String[] args) {  
20:        new DoSomething().go();  
21:    }  
22: }
```

- A. AE
- B. AEBCD

- C. AEC
 - D. AECD
 - E. No output appears other than the stack trace.
8. What is the output of the following snippet, assuming a and b are both 0?
- ```
3: try {
4: return a / b;
5: } catch (RuntimeException e) {
6: return -1;
7: } catch (ArithmeticException e) {
8: return 0;
9: } finally {
10: System.out.print("done");
11: }
```
- A. -1
  - B. 0
  - C. done-1
  - D. done0
  - E. The code does not compile.
  - F. An uncaught exception is thrown.
9. What is the output of the following program?
- ```
1: public class Laptop {  
2:     public void start() {  
3:         try {  
4:             System.out.print("Starting up ");  
5:             throw new Exception();  
6:         } catch (Exception e) {  
7:             System.out.print("Problem ");  
8:             System.exit(0);  
9:         } finally {  
10:            System.out.print("Shutting down ");  
11:        }  
12:    }  
13:     public static void main(String[] args) {  
14:         new Laptop().start();  
15:    } }
```
- A. Starting up
 - B. Starting up Problem
 - C. Starting up Problem Shutting down

- D. Starting up Shutting down
- E. The code does not compile.
- F. An uncaught exception is thrown.

10. What is the output of the following program?

```
1: public class Dog {
2:     public String name;
3:     public void parseName() {
4:         System.out.print("1");
5:         try {
6:             System.out.print("2");
7:             int x = Integer.parseInt(name);
8:             System.out.print("3");
9:         } catch (NumberFormatException e) {
10:            System.out.print("4");
11:        }
12:    }
13:    public static void main(String[] args) {
14:        Dog leroy = new Dog();
15:        leroy.name = "Leroy";
16:        leroy.parseName();
17:        System.out.print("5");
18:    } }
```

- A. 12
- B. 1234
- C. 1235
- D. 124
- E. 1245
- F. The code does not compile.
- G. An uncaught exception is thrown.

11. What is the output of the following program?

```
1: public class Cat {
2:     public String name;
3:     public void parseName() {
4:         System.out.print("1");
5:         try {
6:             System.out.print("2");
7:             int x = Integer.parseInt(name);
8:             System.out.print("3");
```

```
9:      } catch (NullPointerException e) {
10:          System.out.print("4");
11:      }
12:      System.out.print("5");
13:  }
14:  public static void main(String[] args) {
15:      Cat leo = new Cat();
16:      leo.name = "Leo";
17:      leo.parseName();
18:      System.out.print("6");
19:  }
20: }
```

- A. 12, followed by a stack trace for a `NumberFormatException`
- B. 124, followed by a stack trace for a `NumberFormatException`
- C. 12456
- D. 12456
- E. 1256, followed by a stack trace for a `NumberFormatException`
- F. The code does not compile.
- G. An uncaught exception is thrown.

12. What is printed by the following? (Choose all that apply)

```
1: public class Mouse {
2:     public String name;
3:     public void run() {
4:         System.out.print("1");
5:         try {
6:             System.out.print("2");
7:             name.toString();
8:             System.out.print("3");
9:         } catch (NullPointerException e) {
10:             System.out.print("4");
11:             throw e;
12:         }
13:         System.out.print("5");
14:     }
15:     public static void main(String[] args) {
16:         Mouse jerry = new Mouse();
17:         jerry.run();
18:         System.out.print("6");
19:     } }
```

- A. 1
 - B. 2
 - C. 3
 - D. 4
 - E. 5
 - F. 6
 - G. The stack trace for a `NullPointerException`
13. Which of the following statements are true? (Choose all that apply)
- A. You can declare a method with `Exception` as the return type.
 - B. You can declare any subclass of `Error` in the throws part of a method declaration.
 - C. You can declare any subclass of `Exception` in the throws part of a method declaration.
 - D. You can declare any subclass of `Object` in the throws part of a method declaration.
 - E. You can declare any subclass of `RuntimeException` in the throws part of a method declaration.
14. Which of the following can be inserted on line 8 to make this code compile? (Choose all that apply)
- ```
7: public void ohNo() throws IOException {
8: // INSERT CODE HERE
9: }
```
- A. `System.out.println("it's ok");`
  - B. `throw new Exception();`
  - C. `throw new IllegalArgumentException();`
  - D. `throw new java.io.IOException();`
  - E. `throw new RuntimeException();`
15. Which of the following are unchecked exceptions? (Choose all that apply)
- A. `ArrayIndexOutOfBoundsException`
  - B. `IllegalArgumentException`
  - C. `IOException`
  - D. `NumberFormatException`
  - E. Any exception that extends `RuntimeException`
  - F. Any exception that extends `Exception`
16. Which scenario is the best use of an exception?
- A. An element is not found when searching a list.
  - B. An unexpected parameter is passed into a method.



- C. The computer caught fire.
- D. You want to loop through a list.
- E. You don't know how to code a method.

17. Which of the following can be inserted into `Lion` to make this code compile? (Choose all that apply)

```
class HasSoreThroatException extends Exception {}
class TiredException extends RuntimeException {}
interface Roar {
 void roar() throws HasSoreThroatException;
}
class Lion implements Roar { // INSERT CODE HERE
}
```

- A. `public void roar() {}`
- B. `public void roar() throws Exception {}`
- C. `public void roar() throws HasSoreThroatException {}`
- D. `public void roar() throws IllegalArgumentException {}`
- E. `public void roar() throws TiredException {}`

18. Which of the following are true? (Choose all that apply)

- A. Checked exceptions are allowed to be handled or declared.
- B. Checked exceptions are required to be handled or declared.
- C. Errors are allowed to be handled or declared.
- D. Errors are required to be handled or declared.
- E. Runtime exceptions are allowed to be handled or declared.
- F. Runtime exceptions are required to be handled or declared.

19. Which of the following can be inserted in the blank to make the code compile? (Choose all that apply)

```
public static void main(String[] args) {
 try {
 System.out.println("work real hard");
 } catch (_____ e) {
 } catch (RuntimeException e) {
 }
}
```

- A. `Exception`
- B. `IOException`
- C. `IllegalArgumentException`
- D. `RuntimeException`

- E. StackOverflowError
- F. None of the above.

**20.** What does the output of the following contain? (Choose all that apply)

```
12: public static void main(String[] args) {
13: System.out.print("a");
14: try {
15: System.out.print("b");
16: throw new IllegalArgumentException();
17: } catch (IllegalArgumentException e) {
18: System.out.print("c");
19: throw new RuntimeException("1");
20: } catch (RuntimeException e) {
21: System.out.print("d");
22: throw new RuntimeException("2");
23: } finally {
24: System.out.print("e");
25: throw new RuntimeException("3");
26: }
27: }
```

- A. abce
- B. abde
- C. An exception with the message set to "1"
- D. An exception with the message set to "2"
- E. An exception with the message set to "3"
- F. Nothing; the code does not compile.